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Determination Of The Nutritional And Toxiological Effects Of Cod (*Gadus morhua*), Apama (*Sepia* spp) And Ling (*Molva molva*) Stock Fish Sold In Yenagoa, Beyelsa State of Nigeria

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ABSTRACT

This study is centered on determination of the nutritional and toxicological effects of cod (*Gadus morhua*), apama (*Sepia* species) and ling (*Molva molva*) stock fish sold in Yenagoa, Bayelsa State, Nigeria. The study will adopt the experimental research design for the analysis of the stock fish samples. The samples will be separately dried in a laboratory oven at 65OC for 12 hr to obtain a constant dry weight of 0.5g from each sample. Then dried samples will on each ground to powder, using laboratory ceramic mortar and pestle, and sieved with 2mm sieve. Data of this study will be obtained from primary source mainly through laboratory work and through other literatures. All data for the analysis will be analyzed for statistical differences by means of one-way ANOVA and post hoc LSD, on SPSS 27.The result obtained in this study has provided scientific information and detailed knowledge of the proximate, amino acid and fatty acid composition, microbial load, heavy metals and PAHs concentration of these three important stock fish species. The results showed that the fish species had high quality protein, essential and non-essential amino acids, saturated, monounsaturated and polyunsaturated fatty acids. The three stock fishes are excellent sources of fatty acids and amino acids and are good supplement for polyunsaturated omega-3 in diet. The fishes contain essential fatty acids particularly docosahexaenoic acids and eicosapentaenoic acids and essential amino acids for promoting improved health, prevention and healing of wounds and diseases in humans. Overall, cod appears to be best as diet for humans due to its relatively high nutrient components and the ratio of polyunsaturated: saturated fatty acid followed by Apama and ramsi black cod. Sea food such as stock fish and crayfish were found to be potential vectors in the transmission of opportunistic pathogenic microorganisms. This study confirms the occurrence of different pathogens in the samples of stock fish and this could be due to improper handling, improper storage and dirty environment in which they are displayed These could pose potential public health risk if not adequately processed hygienically before consumption. Finally, it was recommended amongst others that traders should buy quantity of product they can sell off within the shortest period to avoid over storage and spoilage.

Keywords: Toxicological, Cod, Apama, Ling (*Molva Molva*) & Stock Fish

INTRODUCTION

Fish is a low fat, high protein food and contains beneficial fatty acids such as omega-3 fatty acids. Omega-3 fatty acids are important for optimal brain and nervous system development in fetuses and infants. Fish constitute more than 60% of the protein intake in adults especially in rural areas (Adeleye, 1992). Fish flesh is tender and is better digested than beef or other types of animal protein (Adebayo-Tayo *et al.,* 2008). Fish acceptability as an alternative protein source cuts across socio-economic, age, religious, and educational barriers.

Fish is an excellent source of essential nutrients, including; protein, Omega-3 fatty acids, vitamins and minerals and low saturated fat content. Fish is an excellent source of high-quality protein, essential for muscle growth and maintenance. Fish is rich in omega-3 fatty acids, particularly EPA and DHA, which are crucial for heart health, brain function, and fetal development. Fish is a good source of various vitamins and minerals, such as vitamin D, vitamin B12, selenium, and iodine. Fish generally has low levels of saturated fat, making it a heart-healthy option.

The health benefits of fish consumption are numerous. Heart health; Omega-3 fatty acids in fish help reduce inflammation, improve blood lipid profiles, and lower cardiovascular disease risk. Brain function; DHA in fish supports brain development, improves cognitive function, and may reduce depression and anxiety symptoms. Fetal development; DHA in fish is essential for fetal brain and eye development during pregnancy. Anti-inflammatory effects; Fish consumption has anti- inflammatory properties, which may reduce chronic disease risk. Improved eye health; Omega-3 fatty acids in fish may reduce age-related macular degeneration risk. The nutritional benefits of fish make it a vital component of a healthy diet. However, it is crucial to consider the potential risks associated with fish consumption, particularly regarding toxic substances.

Fish is an extremely perishable food. The quality of caught fish and its usefulness for further utilization in processing is affected by the fish capture method. Unsuitable fishing method does not only cause mechanical damage to fish, but also creates stress and conditions which accelerate fish deterioration without any preservative or processing measures (Okonta and Ekelemu, 2005). Spoilage proceeds as a series of complex enzymatic, bacterial and chemical changes that begin as soon as the fish dies (Junaid *et al.*, 2010). Fish processing and preservation is carried out mainly to slow down or prevent the enzymatic, bacterial and chemical deterioration of fresh fish.

Akintola *et al.*, (2006) reported different types of preservation methods; drying, smoking, freezing, chilling and brining. But the most prominent fish preservation method in Nigeria is smoke drying. Drying creates a hard outer layer helping to stop microorganisms from entering the food (Junaid *et al.*, 2010).

Stock fish is gutted, beheaded fish (round, split or fillet) produced by natural or industrial drying, without the addition of salt or other additives (Norwegian Industry Standard for fish, 1998). Stockfish can only be made out of cod (*Gadu*s *morhua*), haddock (*Melanogrammus aeglefinus*), saithe (*Pollachius virens*), ling (*Molva molva*) or Task (*Brosmebrosme*).

Aim and objectives of the study

The overall aim of this research is to determine the nutritional and toxicological effects of Cod (*Gadus morhua*), Apama (*Sepia species)* and Ling (*Molva molva*) Stock fish sold in Yenagoa, Bayelsa State, Nigeria.

Specifically this study intends to;

1. determine the proximate composition of *Gadus morhua* (Cod and Apama) and *Anoplopoma fimbria* (black cod) stockfish samples.
2. Ascertain the amino acid and fatty acid composition of these stock fish samples.
3. Determine the heavy metal, polycyclic aromatic hydrocarbons and total petroleum hydrocarbon contents in these stock fish products
4. Evaluate the toxicological effects of these stock fish samples on wistar rats for 28 days by investigating their heamatological indices, liver enzymes, cardiac markers, stress enzymes and lipid prevail.

Research Questions

The following research questions will guide the study.

1. What is the proximate composition of stockfish samples?
2. What is the amino acid and fatty acid composition of these stockfish samples?
3. What is the heavy metal, polycyclic aromatic hydrocarbons, and total petroleum hydrocarbon contents in these stock fish products?
4. What is the toxic effects after feeding these stockfish samples to wistar rats for 28 days?

Significance of the study

The significance of this study lies in its potential to:

Provide vital information on the nutritional profiles of Cod and Black Cod, contributing to the understanding of their potential health benefits and risks. Investigate the presence of toxic substances in these fish species, shedding light on the potential health risks associated with their consumption. Offer insights into the environmental pollution status in Yenagoa L.G.A., Bayelsa State, Nigeria, and its impact on aquatic ecosystems and human health.

Inform consumers, fisheries managers, and policymakers about the safety and quality of Cod and Black Cod in the region, guiding decision-making processes. Contribute to the development of sustainable fisheries management practices, ensuring the long- term availability of these fish species for human consumption.

Enhance understanding of the food chain and ecosystem dynamics in the region, supporting conservation efforts.

Provide a basis for future research on the nutritional and toxicological aspects of fish species in Nigeria, promoting scientific advancement. Support the development of policies and regulations governing fish safety and quality in Nigeria, protecting public health.

Offer valuable insights for the aquaculture industry, enabling the development of safer and more nutritious farmed fish. Contribute to global knowledge on fish nutrition and toxicology, supporting international efforts to ensure food security and environmental sustainability. By investigating the nutritional and toxicological profiles of Cod and Black Cod in Yenagoa L.G.A., Bayelsa State, Nigeria, this study aims to bridge knowledge gaps, inform stakeholders, and promote sustainable fisheries management and public health.

Scope of the study

The scope of this study includes data acquisition through literature review, experimental set-up, collection of stock fish samples, laboratory work and analysis of results generated from the laboratory. *Gadus morhua* (Cod and Apama) and *Anoplopoma fimbria* (black cod) Stockfish samples were purchased from three different markets in Yenegoa LGA of Bayelsa State.

LITERATURE REVIEW

Stock Fish

Fish are aquatic animals that habit, survive and carry out their daily activities in water. There are several species of fishes distributed all over the world, they belong to the kingdom Animalia, phylum chordata and subphylum vertebrata. All the species of fish found in the world are classified into Agnatha (jawless fish), Chrondrichyes (cartilaginous fish), Osteirchthyes (bony fish), Ray finned and Lobe finned fish. Fish is a good source of protein, lipid, fat, essential fatty acids, minerals and vitamins (Paul *et al*., 2018).

Stock fish is made from different species of white fish but cod is the most frequently used fish, cod fish belong to a group of fish called Osteirchthyes meaning bony fish. There are several species of cod, they are named according to their habitats and other characters (such as colour, structure and swimming pattern) they include; *Gradus morhua* (Atlanta cod), *Molva molva* (lingcod), Green cod, Pacific cod, *Pollachius vireus* (saith), Tusk (*Brosme brosme*), *Pollachius pollachius*, Haddock (*Melaogrammus aeglefinus*), Vicenza cod, Bacalhau cod, Norwegian cod, Murray cod and Alaska Pollock (Akin *et al.,* 2015).

The cod used in stock fish production are usually harvested in fresh water so they are usually salted two weeks before drying. According to Abiodum *and Blessing* (2016) stock fish is one of the foreign fish which are distributed to many countries mostly in Nigeria, this is because the fish is not found in any part of the country, the fish is locally known as Okporoko among the Igbos, Bazabaza among the Benins and kpanla among the western part of the country. Fish generally are important source of protein and vitamins needed by human and animals to maintain tissues and cells, and it's mostly consumed more than meat claimed (Akinwumi and Kehinde, 2015).

Plate 1 Fresh *Gadus morhua* stockish

Plate 1b: Dried *Gadus morhua* stockfish (Cod)

Heavy Metals

The term "heavy metals" refers to any metallic element that has a relatively high density and is toxic or poisonous even at low concentration (Lenntech, 2004). "Heavy metals" is a general collective term, which applies to the group of metals and metalloids with atomic density more preponderant than 4 g/cm3, or 5 times or more, more preponderant than water (Huton and Symon, 1986; Battarbee *et al.*, 1988; Nriagu and Pacyna 1988; Nriagu, 1989; Garbarino *et al.*, 1995, Hawkes, 1997). However, heavy metal has little to do with density but concerns chemical properties. Heavy metals include lead (Pb), cadmium (Cd), zinc (Zn), mercury (Hg), arsenic (As), silver (Ag) chromium (Cr), copper (Cu) iron (Fe), and the platinum group elements.

Heavy metals have caused major human health quandaries in sundry components of the world. The overt toxicity of some of these elements has been apperceived for many years; indeed, the inimical effects of lead were kenned as far back as the second century BC in archaic Greece. Over the years, medicos became increasingly acclimated with the symptoms of metal poisoning arising in occupationally exposed workers and in individual cases of poisoning. In more recent times, toxicologists concerned with metal poisoning endeavored to elucidate the metabolism and range of effects induced by metals in these two populations. Such studies revealed that certain effects only become ostensible at particular stages of the exposure scale. In cases of high exposure, clinical signs and symptoms can be observed. At lower exposure levels clinical manifestations may be absent but effects may be observed at the physiological or biochemical level. From the mid-1950s to the early 1960s it was apperceived that poisoning by some of these elements was not restricted to occupationally exposed workers or to the infrequent individual. In the USA, detailed studies by health officials revealed that many hundreds of cases of childhood lead poisoning occurred every year in the dilapidated housing areas of the older cities. At about the same time in Japan, major environmental poisoning incidents caused by methyl mercury and by cadmium were the subject of excruciating scientific investigation and magnetized public attention and concern. Possibly less prominent but withal occurring in Japan over the same duration were two mass incidents of arsenic poisoning. These major episodes have prompted numerous studies of other populations considered to be subjected to elevated exposure levels from a variety of sources. Such studies, employing increasingly sophisticated techniques, revealed that effects could be detected at exposure levels which had antecedently been considered safe.

MATERIALS AND METHODS

Materials

Equipment/Apparatus

Standard and calibrated equipment and apparatus were used in this study

Reagents and Chemicals

All reagents and chemicals used in this study are of analytical grade.

Collection of samples

a. Purchase of Stock fish Samples

Specimens of three popular species of imported stockfish namely Cod, Apama and black cod stockfish samples were purchased from retailers in three popular markets (Swali ultra-modern market, Tombia junction market and Kaiama market) in Yenagoa L.G.A of Bayelsa state, Nigeria. These species were imported from Norway into Nigeria and are highly cherished as sources of protein especially by their consumers. From each species, a set of stockfish were randomly collected and transported in sterile polyethene bags to the laboratory for analysis.

Sample preparation

The samples were separately dried in a laboratory oven at 65^{O}C for 12 hr to obtain a constant dry weight of 0.5g from each sample. Then dried samples were each ground to powder, using laboratory ceramic mortar and pestle, and sieved with 2mm sieve.

Determination of Proximate Composition

Proximate analysis to determine the moisture, crude protein, fat, ash, fiber and total carbohydrate contents of the samples were carried out according to the standard methods (AOAC, 2006).

Determination of Moisture Content Procedure

An empty silica dish was allowed to cool in the desiccator, after which its weight was taken. Then 1.0g of the sample was weighed into the silica dish and placed in the oven at about 105^{o}C for 24 hours. It was cooled in desiccator to the room temperature. The silica dish and contents was weighed and later placed back in the oven for another 24 hours to ensure complete drying. The cooling process in the desiccator was repeated until a constant weight was obtained.

Determination of Ash Content Procedure

To a pre-weighed, clean, empty petri-dish, 1.0g of the sample was added and placed in the muffle furnace at 550^{o}C for 4 hours. The sample was allowed to cool in the desiccator. This was repeated until a constant weight was obtained. The weight of the petri-dish and residue was taken.

Determine of the Protein Content Procedure

Digestion

To 1.0g of the sample in a 100ml Kjeldahl digestion flask, was added 3g of Kjeldahl digestion catalyst, 20ml of the 1.25% concentrated sulphuric acid and a few anti-bumping agents. The flask was fitted to a reflux condenser and gently heated until foaming had ceased, and the contents became completely liquefied. Then the content of the flask was heated intensely, with occasional rotation of the flask, until the colour of the digest changed from ash to blue-green or pale green colour. The flask was allowed to cool and its contents were quantitatively transferred into a 100ml volumetric flask and made up to the 100ml mark with distilled water.

Distillation

Twenty ml of this diluted digest was transferred into a 150ml distillation flask. The flask into which some anti-bumping chips have been added was connected to a condenser whose receiver was attached to a Buchner funnel immersed in a 400ml beaker containing 10ml of 2% boric acid solution masked with 2 drops of double (methyl red-methylene blue) indicator. Then, 20ml of 40% NaOH solution was added to the flask using a syringe. Distillation was stopped when the volume in the beaker was about the same in the original volume, and the colour of the boric acid in the receiver flask changed from purple to pale green. The ammonia was liberated into the boric acid solution. The distillation unit was dismantled and rinsed with distilled water.

Titration

The distillate (boric acid-ammonia solution) was titrated with 0.1M hydrochloric acid, until the colour changed to pink, which marked the end of titration. The titre value was recorded and this was used to determine the nitrogen content from which the protein value was calculated by multiplying with the Nitrogen factor, 6.25.

Determination of the Crude fat content Procedure

Extracting flasks (250ml) capacity was dried in the oven at 105^{o}C, transferred to the desiccator to cool to the laboratory temperature and their weights were measured. Petroleum ether (250ml) was measured into the dried flasks while 0.25g of the sample was weighed into labelled porous thimbles and placed in the condenser of the soxhlet extractor, and the sample was extracted for 4 hours. The thimbles were removed with care and the petroleum ether in the top container (tube) was collected for reuse. The extraction flask was removed from the heating mantle arrangement when it was almost free of petroleum ether. The extraction flask with the oil was oven dried at 105^{o}C for the period of 1 hour. The flask containing the dried oil was cooled in the desiccator and the weight of the cooled flask with the dried oil was measured.

Determination of the Fiber Content Procedure

Two grams of the pulverized sample was weighed into 1 litre conical flask and 200ml of 1.25% sulphuric acid was added and allowed to boil gently for 30minutes and contents were filtered through the Buckner funnel and rinsed well with hot deionised water. To the filtrate 200ml of the boiling 1.25% of sodium hydroxide was added, allowed to boil gently for 30minutes and later filtered through the Buckner funnel. The residue was washed with hot demonized water, with 10% hydrochloric acid, and then followed by dimethyl ether and then dried in oven overnight at 110ºC. The residue was then transferred into the desiccator to cool before weighing. After weighing, it was ashed in the muffle furnace at 550ºC for 90 minutes. After ashing, it was transferred to the desiccator to cool and then weighed.

FINDINGS OF THE STUDY

Results of nutritional studies on cod, apama and Ramsi black cod.

Table 4.1: Proximate composition (%) of the analyzed samples of cod, apama and Ramsi black cod purchased from three popular markets in Yenagoa LGA, Bayelsa State.

Parameters	Cod	Apama	Ramsi black cod
Fibre Content	3.85	8.87	6.73
Fat Content	2.63	12.12	1.44
Ash Content	8.52	7.42	6.59
Moisture Content	10.83	13.50	13.87
Protein	13.30	11.20	10.50
Carbohydrate	60.83	46.86	60.85

The results of investigation of the proximate composition (%) of the stock fish samples are presented in table 4.1 above. The fibre and fat contents were seen to be higher in Apama (8.87 and 12.12 % respectively) when compared with cod (3.85 and 2.63 %) and ramsi black cod (6.73 and 1.44 %). The ash and moisture contents were observed to be higher in cod (8.52) and ramsi black cod (13.87 %) respectively when with apama. Protein was higher in cod (13.30 %) while carbohydrates were seen to be higher in ramsi black cod.

Table 4.2: Amino acid Profile of Cod, Apama and Ramsi black cod purchased from three popular markets in Yenagoa LGA, Bayelsa State.

Amino Acids (g/100g of Protein)	**Cod**	**Apama**	**Ramsi black cod**
Glycine	3.88	4.04	3.54
Alanine	4.07	4.22	3.98
Serine	4.83	5.47	4.83
Proline	3.90	4.03	4.33
Valine	4.74	5.26	4.83
Threonine	4.28	4.37	3.69
Isoleucine	4.49	4.83	4.13
Leucine	7.43	7.78	7.20

Aspartate	12.20	12.09	12.07
Lysine	6.28	6.31	6.11
Methionine	1.54	1.59	1.30
Glutamate	14.70	15.23	14.67
Phenylalanine	5.13	5.34	5.08
Histidine	2.87	2.96	2.31
Arginine	5.66	6.24	5.37
Tyrosine	2.97	2.98	3.39
Tryptophan	1.23	1.18	1.15
Cystine	1.43	1.22	1.30

The result of the amino acid profile of Cod, Apama and Ramsi black cod are shown in table 4.2 above. Eighteen amino acids were screened in the stock fish samples and glutamate was seen to be higher in all the stock fish samples (14.70, 15.23 and 14.67 g/100g of Protein) followed by aspartate (12.20, 12.09 and 12.07 g/100g of Protein) for cod, apama and ramsi black cod respectively when compared with the other amino acid.

Table 4.3: Fatty acid composition (µg/ml) of Cod, Apama and Ramsi black cod purchased from three popular markets in Yenagoa LGA, Bayelsa State.

Fatty acids (µg/ml)	Number of carbon Atom	Type of fatty acids	Cod	Apama	Ramsi black cod
Lauric acid	C12:0	SFA	6.63	2.74	ND
Myristic acid	C14:0	MUFA	13.08	6.47	12.36
Hexadecanoic	C16:0 acid	SFA	21.84	7.08	26.67
Stearic acid	C18:0	SFA	ND	0.01	6.67
Oleic acid	C18:1	MUFA	14.46	4.99	41.05
Linoleic acid	C18:2	PUFA	1.97	10.42	39.64
Linoleicacid	C18:3 (Omega 3)	PUFA	17.30	34.15	12.15
Eicosadienoic	C20:2 acid	PUFA	7.20	2.39	3.12
Eicosatrienoic 3)	C20:3 acid (Omega	PUFA	9.33	3.69	2.35
Cetoleic acid	C20:4	PUFA	4.65	0.37	5.67
Eicosapentaenoic	C20:5 acid	PUFA	0.01	3.10	3.68
Docosahexaenoic acid	C22:6	PUFA	ND	ND	3.04

ND = Not Detected; SFA=Saturated Fatty Acid; MUFA=Monounsaturated Fatty Acid PUFA=Polyunsaturated Fatty acid.

The result of the fatty acid composition (µg/ml) of Cod, Apama and Ramsi black cod is shown in table 4.3 above. The result shows that twelve fatty acids were seen in the stock fish samples analysed. For cod, Hexadecanoic acid was seen to be higher (21.84 µg/ml), apama, omega 3 fatty acid, Linoleic acid (34.15 µg/ml) while ramsi black cod had oleic acid (41.05 µg/ml) to be higher. Other saturated, monounsaturated and polyunsaturated fatty acids were also observed in the stock fish samples analysed.

Microbial studies on Cod, Apama and Ramsi black cod purchased from three popular markets in Yenagoa LGA, Bayelsa State.

Table 4.4: Total heterotrophic bacteria count of Cod, Apama and Ramsi black cod purchased from three popular markets in Yenagoa LGA, Bayelsa State.

Stock fish type	Total Heterotrophic Bacteria count **(THB) (CFU/g)**
Cod	$7.8x10^{7}$
Apama	$5.5x10^{7}$
Ramsi black cod	$10.6x10^{7}$

Table 4.5: Bacterial isolates, number of occurrence and percentage occurrence of Cod, Apama and Ramsi black cod purchased from three popular markets in Yenagoa LGA, Bayelsa State.

Stock fish type	**Bacterial Isolate**	**Number of occurrence**	**Percentage (%) of occurrence**
Cod	*Candida albicans*	2	14.2
	sp.	1	7.1
	Rhizophus oryzae	7	50
	sp.	1	7.1
	Aspergillus niger	2	14.2
	sp.	1	7.1
	Proteus sp.		
	Micrococcus sp.		
	Pseudomonas sp.		
Apama	*Aspergillus niger*	8	57.1
	sp.	1	7.1
	Candida albicans	2	14.2
	sp.	3	21.4
	Penicillium sp. Rhizopus oryzae sp.		
Ramsi black cod	*Bacillus sp.*	7	20.6
	Staphylococcus sp.	7	20.6
	Micrococcus sp.	10	29.4
	Proteus sp.	3	8.8

The result of the microbial studies carried out on Cod, Apama and Ramsi black cod are shown in tables 4.4 and 4.5 above. The total heterotrophic bacteria count was seen to be higher in ramsi black cod ($10.6x10^7$ CFU/g) when compared with cod ($7.8x10^7$ CFU/g) and apama ($5.5x10^7$ CFU/g). *Aspergillus niger sp* was seen to have the highest occurrence in cod and apama (50% and 57.1% respectively) while *Micrococcus sp.* was seen to occur more in ramsi black cod (29.4%).

Heavy metals concentration, polycyclic aromatic hydrocarbons and total petroleum hydrocarbon content of Cod, Apama and Ramsi black cod purchased from three popular markets in Yenagoa LGA, Bayelsa State.

Table 4.6: Heavy metal composition (mg/kg) of Cod, Apama and Ramsi black cod purchased from three popular markets in Yenagoa LGA, Bayelsa State.

Parameters	**Cod**	**Apama**	**Ramsi black cod**
Cadmium	0.027	0.018	0.028
Arsenic	0.008	0.010	0.018
Lead	0.043	0.036	0.030
Mercury	0.022	0.017	0.027

Table 4.7: Maximum acceptable limits of the measured toxic metals in Seafood and fish

Measured toxic metals	**Maximum limit(mg/kg)**	**References**
Cadmium	0.5	FAO/WHO(1983)
Lead	0.5	FAO/WHO(1983)
Mercury	0.001	FAO/WHO(1983)
Arsenic	76	USFDA(1993

The results of the concentration of four heavy metals analysed in cod, apama and ramsi black cod are shown in table 4.6 above with the maximum acceptable limit of these analysed metals shown in table 4.7 above. From the results above, cadmium, arsenic and lead were seen to be below the permissible limit set by the regulatory agencies. Mercury was seen to be high in all the stock fishes analysed with ramsi black cod having the highest value (0.027mg/kg) followed by cod (0.022mg/kg) and apama (0.017mg/kg) when compared with the maximum limit of 0.001mg/kg.

Table 4.8: Polycyclic aromatic Hydrocarbon (PAHs) concentration of Cod, Apama and Ramsi black cod (mg/kg) purchased from three popular markets in Yenagoa LGA, Bayelsa State.

Parameters	Cod	Apama	Ramsi black cod
Fluorene	0.001	BDL	BDL
Fluoranthene	0.613	0.375	0.554
Phenanthrene	0.019	0.087	0.224
Dibenzyl(a,h) anthracene	BDL	0.004	0.004
Anthracene	0.053	0.035	0.026
Acenaphthene	0.004	0.004	0.004
Benzo(k)fluoranthene	0.010	0.006	0.013
Benzo(a)pyrene	0.012	0.012	0.012
Xylene	0.003	0.005	0.011
Pyrene	0.009	0.009	0.009
Benzo(g,h,i)perylene	0.087	0.166	0.166
Benzo(b)fluoranthene	0.967	0.164	0.069

Key: BDL – Below Detection Limit (0.001mg/kg)

The result of the polycyclic aromatic hydrocarbon (PAHs) concentration of Cod, Apama and Ramsi black cod sold in three popular markets in Yenagoa LGA of Bayelsa state are shown in table 4.8 above. Twelve PAHs were assessed for in the three stock fish samples and in cod, Benzo(b)fluoranthene (0.967mg/kg) and fluoranthene (0.613mg/kg) were seen to be high when compared with other PAHs. In apama and ramsi black cod, fluorine was BDL of 0.001mg/kg and fluoranthene concentration was found to be high with values of 0.375mg/kg and 0.554mg/kg respectively when compared with other PAHs.

DISCUSSION OF FINDINGS

Nutritional studies on cod, apama and Ramsi black cod sold in three popular markets in Yenagoa LGA of Bayelsa state, Nigeria. Fish is a highly proteinous food consumed by the populace; A larger percentage of consumers do eat fish because of its availability, flavors, palatability while fewer percentage do so because of its nutritional value. Therefore, studies on the proximate composition and elemental composition of the fishes have not really caught attention of researches in fisheries; Hence the consumer and fishery workers are left with limited or paucity of information on the importance of particular fish species in their daily diets (Adewoye *et al.,* 2003).

The results of investigation of the proximate composition (%) of the stock fish samples purchased from three popular markets in Yenagoa LGA of Bayelsa state are presented in table 4.1 above.

The crude fibre and fat contents were seen to be higher in Apama (8.87 and 12.12 % respectively) when compared with cod (3.85 and 2.63 %) and ramsi black cod (6.73 and 1.44 %). The ash contents were observed to be higher in cod (8.52%) with apama having the value of 7.42% and ramsi black cod, 6.59%. For moisture content, 13.87 %, 13.50% and 10.83% values were seen for ramsi black cod, apama and cod respectively. Crude protein level was higher in cod (13.30 %), apama (11.20%) and ramsi black cod (10.50) while carbohydrates were seen to be higher in ramsi black cod (60.85%) followed by cod (60.83%) and apama (46.86%).

The crude fat content of the stockfish samples reported by Adeyeye and Olaleye, 2022 were relatively low in the range 2.55 – 3.85g/100g with mean value of 3.80+ 0.492. These values were lower than 5.35g/100g and 6.26g/100g in adult bee and maize weevil respectively (Adeyeye and Olaleye, 2016), 14.2g/100g in beef jerky meat (Adeyeye *et al.,* 2020) and 18.4g/100g in Nigerian local cheese (Adeyeye *et al*., 2021). Crude fat in this study are cod (2.63%), apama (12.12%) and ramsi black cod (1.44%). This is not surprising as stockfish is one of the lean fishes expected to have low fat content. The values recorded in this research agree with Adeyeye and Ayejuyo (2007) who reported the following for organs in turkey (g/100g): muscle (2.12) and skin (12.1). However, crude fat in this study was higher than 1.16-1.91g/100g in the muscle of different fish species from Muthupettal mangroves (Suganthi *et al*., 2015).

The levels of moisture content in the samples; 13.87 %, 13.50% and 10.83% for ramsi black cod, apama and cod respectively were comparatively higher than the following literature values (g/100g): mean values of organs of duck (2.88 + 1.40) (Adeyeye, 2020), pouch rat (3.23 + 2.02) (Adeyeye and Adesina, 2018) and *Numidia meleagris* (2.99 ± 1.75) (Adeyeye and Adesina, 2014). High levels of moisture content in the stockfish samples would affect the preservation quality of the samples as high moisture content promotes microbial activities in the samples during storage thereby exposing the samples to microbial attack.

Total ash content could be used to roughly estimate the mineral content of any given sample; the higher the total ash, the higher the mineral content. High levels of ash in the samples could therefore predict the samples to be good sources of mineral elements.

The crude protein contents of the stock fish samples analysed were very high, confirming the literature reports that fish is a very good source of protein. The results of the of protein content recorded in this research were within the range of variations reported by Zelibe (1989). The stock fish species may therefore be an ideal source of animal protein for use in controlling diets. The high tissue protein content of the fish species in this study may be related to the high protein contains of their common diets as they fed mostly on fish items, crustaceans, molluscs, algae and diatoms (Osibona, 2005).

The carbohydrate content recorded in the analysed fish samples were observed to be 60.85% in ramsi black cod followed by cod (60.83%) and apama (46.86%). These values suggest that these stock fish samples could be a good source of carbohydrates and could be used the diet therapy.

The physiological role of proteins is to provide substrates for the syntheses of body proteins and other important nitrogen-containing compounds, and building, repair, and maintenance of the body. Amino acids are associated with health problems and their deficiencies lead to many diseases, hence, knowledge of the amino acid composition of foods might be the basis for the establishment of their potential nutritive values. The results for the essential and non-essential amino acid profiles of cod, apama and ramsi black cod purchased from three popular markets in Yenagoa LGA of Bayelsa state are shown in table 4.2 above. Results from this study showed the presence of eighteen amino acids in the stock fish samples and glutamate was seen to be higher in all the stock fish samples (14.70, 15.23 and 14.67 g/100g of Protein) followed by aspartate (12.20, 12.09 and 12.07 g/100g of Protein) for cod, apama and ramsi black cod respectively when compared with the other amino acids. Among these 18 amino acids are 10 nutritionally functional amino acids (FAAs) including arginine, cysteine, leucine, methionine, tryptophan, tyrosine, aspartic acid, glutamic acid, glycine, and proline, which are involved in the regulation of key metabolic pathways to improve health, growth, and development, and reproduction in organisms (Wu, 2010 and Wu, 2013) and seven conditionally essential amino acids (CEAAs), which are non- essential amino acids that become conditionally indispensable in times of illness, extreme trauma, surgery, thermal injury, sepsis, etc (Postnauer, 2010) and they include arginine, lysine, glutamic acid, tyrosine, glycine, proline, and serine. The nutritionally essential amino acids in food are the primary determinants of the nutritional quality of proteins (Young and Pellet, 1984). There were observed high values in the protein content of the three stockfishes studied, which might be due to factors like the season of the year, availability of food, migration, feeding habit and rate of feeding, habitat, age, size, reproductive cycle, and genetic trait (Abdullahi,2001). The quantity and quality of amino acids in the stockfishes studied showed that they are good sources of protein. The functions of these amino acids in the body have been reported (Ibegbulem *et al.,* 2012 and Wu *et al.,* 2013), and the results of this research showed that proteins from the meats of the species of stock fishes studied have amino acids with biological values that can meet human demand for essential amino acids. The nutritive value of meat from any animal is determined by the presence of more essential amino acid in its protein (Abdel-Salam, 2014).

Fatty acid analysis of the three stock fish samples indicated the presence of different categories of fatty acids, saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs). The result of the fatty acid composition (µg/ml) of Cod, Apama and Ramsi black cod is shown in table 4.3 above. The result shows that twelve fatty acids were detected in the stock fish samples analysed. For cod, hexadecanoic acid was seen to be higher (21.84 µg/ml), apama, omega 3 fatty acid, Linoleic acid (34.15 µg/ml) while ramsi black cod had oleic acid (41.05 µg/ml) to be higher. Other saturated, monounsaturated and polyunsaturated fatty acids were also observed in the stock fish samples analysed. The predominant fatty acid in saturated fatty acid family was hexadecanoic acid (C16:0; cod: 21.84, apama: 7.08 and ramsi black cod: 26.67), however, stearic acid (C18:0; cod: ND, apama: 0.01 and ramsi black cod: 6.67) exhibited the lowest proportion. Myristic acid and Oleic acid were the only MUFAs identified. The PUFAs family was abundant in the three stock fishes analysed. The highest observed PUFAs levels are linked to the high content of n-3 Fatty acid series, mainly represented by eicosapentanoic acid (EPA) and Linoleic acid. The result is inagreement with Ben *et al.* (2014). Fishes are generally rich in n-3 fatty acids and low in n-6 family (Rioux and Legrand, 2001). These groups of fatty acids are known to have beneficial effects for human health (FAO, 2013). The fatty acids composition of the three stock fishes used in this study was in agreement with the data available on the fatty acid composition of the fish species reported by Ackman (1980). Several authors have concluded that fatty acid profiles in fish reflect the diets of the animals (Gatlin and Stickney, 1982; Linko *et al.,* 1985; Ogata and Murai, 1989; Watanabe *et al.,* 1989; Turner *et al.,* 1990). In addition to diet composition, the spawning activity of these fish could drain their fat reserves, thereby contributing to the variability of the fatty acids and low tissue lipids.

Microbial studies on Cod, Apama and Ramsi black cod purchased from three popular markets in Yenagoa LGA, Bayelsa State. The result of the microbial studies carried out on cod, apama and ramsi black cod purchased from three popular markets in Yenagoa LGA of Bayelsa state are shown in tables 4.4 and 4.5

above. The total heterotrophic bacteria count was seen to be higher in ramsi black cod ($10.6x10^7$ CFU/g) when compared with cod ($7.8x10^7$ CFU/g) and apama ($5.5x10^7$ CFU/g). *Aspergillus niger sp* was identified in the three stock fishes but was seen to have the highest occurrence in cod and apama (50% and 57.1% respectively) while *Micrococcus sp.* was seen to occur more in ramsi black cod (29.4%).

Fungi isolated in this study concur with findings by other authors however, Refai *et al.*2004 reported that *Penicillium* spp, *Aspergillus spp* and *Rhizopus spp* are normal mycoflora present in most fish. Notwithstanding, many fungal genera have virulence factor which cause toxin elaboration under favourable predisposing environment. Ecology is also an important factor which influences the diversity of fungus genera on fish and their eggs (Hussein *et al.,* 2001). According to Pailwal *et al.* (2000), diversity of water molds depends upon the interaction of physiochemical factors. This fungal may be due to the differences in the biochemical composition of these fish species and to which different moulds and yeast react differently (Doe, 2013).

It is important to state that majority of the fungal agents isolated were of medical significance. The occurrence of *Aspergillus spp,* could lead to mycotoxin elaboration and when consumed, they induce gastrointestinal and metabolic disturbance (Martin 2008).

The source of fungal contamination can also be as a result of consumption of fungal contaminated feed present in the pond. Moreover, the decomposition of these feed also add to increase in fish contamination: particularly, poor pond management, injured fish, or fish having other forms of diseases. Fungal pose wide contamination threat in fish farming mainly due to mismanagement of ponds (Willoughby, 1997).

Handling of fish could also engender microbial contamination especially in artisanal fishery due to unhygienic methods of reducing temperature. During the drying period, smoke kilns used in artisanal fishery and the over loading of the fish in the trays leads to improper processing which in turn encourages fungal attack (Eyo, 2012 and Akande and Tobor, 2012). During storage of dried fish product, good storage product practices are not observed by most wholesalers such as improper ventilation and easy access of pest into the storage environment.

The environment where fish are displayed in the market are usually unhygienic and this could constitute another avenue for microbial attack and dried and stock fish samples in open trays beside refuse heaps encourages fungal attack through air droplet (Akande and Tobor, 2012).

This study shows that all the stockfish samples obtained from the three popular markets in Yenagoa were contaminated with bacteria. The higher total heterotrophic bacteria count obtained in the three samples of stock fishes may be due to contamination by sellers and buyers. This is similar to the findings of Junaid *et al*. (2010). The presence of these bacteria in the stockfish samples might probably make the consumption of these stockfishes hazardous to health as similarly reported by Adebayo – Tayo *et al.,* (2008).

The microbial counts obtained in this study are higher than all available standards for food and fishes except for the zero-coliform recorded from all samples. It is also important to pinpoint the fact that the samples studied are not meant to be eaten raw and should be cooked before consumption. Therefore, there is likelihood of denaturing the microorganisms isolated before consumption.

Heavy metals concentration, polycyclic aromatic hydrocarbons and total petroleum hydrocarbon content of Cod, Apama and Ramsi black cod purchased from three popular markets in Yenagoa LGA, Bayelsa State.

Diet represents the most relevant source of majority of metals for non-occupationally exposed populations. The relevance of metals in human health and disease is well documented. Arsenic is classified as a Group 1 human carcinogen by the World Health Organization – International Agency for Research on Cancer (IARC, 2004). The toxicities associated with chronic ingestion of inorganic arsenic (As) in humans include skin lesions, cancer, developmental toxicity, cardiovascular diseases, derangement in glucose metabolism, and diabetes. Cadmium (Cd) is a naturally occurring, poorly excreted divalent element classified as non-essential toxic metal which can bioaccumulate in humans (ATSDR, 2012). Although inhalation and dermal contact are known routes of exposure, dietary Cd is the most significant source of exposure in humans through meat and offal (Darwish *et al.,* 2008). Cadmium is a Group I carcinogen according to IARC and causes multi-organ toxicity namely hepato-renal toxicity, developmental neurotoxicity, cardiovascular toxicity, osteomalacia, deficiencies of essential trace elements (IARC, 1993). Lead (Pb) is a class 2A carcinogen (IARC, 2006). In adults, Pb-induced neuro-toxicity manifests as both sensory and motor impairments. Lead has also been implicated in both male and female infertility including miscarriages, cardiovascular diseases, anemia, irritability, osteoarthritis, headaches, constipation, weight loss, joint pain, and muscle weakness. Mercury (Hg) is a ubiquitous environmental pollutant. It is common resident in atmospheric deposition with the primary organic form methylmercury found in the food chain from where microbial action converts it to inorganic Hg (Zupo *et al.*, 2019). Exposure to methylmercury may lead to learning and behavioral deficits, cardiovascular diseases, and reproductive impairments (Morgano *et al.*, 2011; Chen *et al.*, 2020; Santos-Lima *et al.*, 2020; Yao *et al.*, 2020). Vanadium (V) has epidemiological evidence of genotoxicity (Altamirano-Lozano *et al.*, 2014).

Among several contaminants, metals are the most persistent because they are not biodegradable (Okoye *et al.*, 2021). This imply that they may bioaccumulate in the food chain and pose a threat to human health. In addition, since malnutrition is a principal cause of death in sub-Sahara Africa, the assurance of food safety of the sub-Sahara Africa's natural resources is of immense importance and a periodical estimation of metals' dietary intake and of consequent health risks through comparison with tolerable levels, is needed to evaluate the long-term risk for public health. In health risk assessment, the expression "tolerable" is used because it describes permissibility rather than acceptability for the intake of contaminants associated with the consumption of foods. Many metals are not removed rapidly from the human body, and hence provisional tolerable weekly intake (PTWI) and/or provisional tolerable monthly intake (PTMI) are provided by JECFA and EFSA, as first step in assessing of dietary exposure to metals (Morgano *et al.*, 2011). As second step, the margin of exposure (MOE) is used to characterize the health risk associated to metals dietary exposure and evaluate efficacy of the actual risk management actions.

Metals pollution of sediments, farmlands (where animals graze), groundwater and seawater is a major public health concern in Niger Delta area of Nigeria (Okogbue *et al.*, 2017; Igwe et al., 2021). The dietary intake assessment of metals in different age groups of the Niger Delta showed Pb intake trough meat and fish consumption for both adults and children exceeded the tolerable limits set by EFSA that may adversely impact the health of Niger Delta population (Okoye *et al.*, 2021). In view of the above evidences, this study explored the characterization of health risks associated to the dietary intake of metals in Nigerian children, adolescent, adult and senior population by using i) the ratio between estimated weekly intake (EWI) or estimated monthly intake (EMI) and the PTWI or PTMI, provided by international food authorities, in order to describe the potentially harmful exposure associate to commonly food Nigerian products; ii) the MOE calculation as useful tool to support risk managers in defining possible actions required to keep metals exposure as low as possible and the improvement of public health and hygiene in Nigeria.

The results of the concentration of four heavy metals analysed in cod, apama and ramsi black cod are shown in table 4.6 above with the maximum acceptable limit of these analysed metals shown in table 4.7 above. From the results above, cadmium, arsenic and lead were seen to be below the permissible limit set by the regulatory agencies.

Because of the harm that cadmium does to humans, animals, and plants, it is much more of a problem. The debilitating condition referred to as Itaiitai disease, characterized by joint destruction, bone weakening, bodily atrophy, and a distressing fatality, has been attributed to the toxic heavy metal cadmium. Lead is believed to be the causative agent of the medical condition referred to as plumbism. Aquatic biomass contains concentrations of lead that go up the food chain to reach human consumers. Lead is also known to harm the reproductive system, kidneys, liver, brain, central nervous system, and other organs. Mercury was seen to be high in all the stock fishes analysed with ramsi black cod having the highest value (0.027mg/kg) followed by cod (0.022mg/kg) and apama (0.017mg/kg) when compared with the maximum limit of 0.001mg/kg.

The data presented in this study indicated that the concentrations of measured toxic metals differ from one stockfish to another. The mercury concentration in the three stock fish head analysed was above the maximum limit of 0.001mg/kg was seen to be higher in ramsi black cod. Mercury occurs naturally, large amounts enter the aquatic environment from anthropogenic sources (Atuanya *et al.,* 2011). Eating contaminated fish is the major source of human exposure to methyl-mercury. The populations most sensitive to the compound are fetuses, infants, and young children. Consequently, fish consumptions by pregnant women, young children and women of child bearing age is a particular cause of concern because of the likelihood of mercury exposure. Methyl-mercury, an organic compound, is the most toxic form of mercury to which humans are normally exposed. Methyl- mercury bioaccumulates with larger fish, which eat smaller ones, containing much higher levels than non-predatory fish (Physicians for Social Responsibility, 2004).

The observed levels of toxic metals are consistent with that reported in some species of fish (Akoto *et al.,* 2014). The accumulation of high levels of toxic metals in food may result in serious system health effects, hence various organizations and regulatory bodies of some countries have established the maximum limits of concentrations of toxic metals that could be acceptable (Xu *et al.,* 2012 and Chary *et al.,* 2008). Previous studies have reported lower concentrations than we observe in some species of stockfish (Eze and Ogbuehi, 2015, Mukherjee and Kumar, 2011 and Afonso *et al.,* 2005). It was observed that cod and similar species can accumulate toxic metals which could be hazardous to consumers (Afonso *et al.,* 2005). They reported lower levels of toxic metals and concluded that the observed levels though low, were higher than the maximum limit recommended by the regulatory bodies. Our observation completely disagree with that reported by Eze and Ogbuehi in 2015. WHO reported that Cd, Pb, Hg and As were below detectable limit (0.001mg/kg) and concluded that the health assessment does not suggest risk status from their consumption.

Even though the above-mentioned studies evaluated toxic metal concentration in body tissue of stockfish, the concentrations we observed in this present study were higher and could represent potential health risks in consumers. More so, the habit of consuming head bones and gills should be discouraged because of the higher concentrations of Cd and Pb in the gills. Higher concentrations of Cd and Pb were previously reported in the gills than muscle tissues of other species of fish (Edem *et al.,* 2009). The higher toxic metal levels observed in gills may be due to the important roles gills play in the normal physiology of aquatic animals. The gills are the sites of gas exchange, ion regulation, acid balance and waste excretion (Shukla *et al.,* 2007 and Bajc *et al.,* 2005). Studies have shown high levels of toxic metals in other species of fish commonly consumed in Nigeria (Babatunde *et al.,* 2012 and Edem *et al.,* 2009). Babatunde *et al,*. 2012 reported that the concentrations of nickel and chromium found in 5 different species of fresh water fish were higher than the maximum permissible limits for human consumption but the levels of cd, Pb and cobalt were lower. Other sources of contamination could be through air, environment and food.

The bio-toxicological effects of heavy metals refer to the harmful effects of toxic metals to the body when consumed above the recommended limits which may lead to learning disabilities impaired protein and hemoglobin synthesis, severe anemia, renal failure depending on the toxic metal involved. Accumulation of Cd could lead renal impairment, fragile bones and male reproductive challenges (Emokpae and Adobor 2014). Polycyclic aromatic Hydrocarbon (PAHs) concentration of Cod, Apama and Ramsi black cod purchased from three popular markets in Yenagoa LGA, Bayelsa State.

The result of the polycyclic aromatic hydrocarbon (PAHs) concentration of Cod, Apama and Ramsi black cod sold in three popular markets in Yenagoa LGA of Bayelsa state are shown in table 4.8 above. Twelve PAHs were detected in the three stock fish samples and in cod, Benzo (b) fluoranthene (0.967mg/kg) and fluoranthene (0.613mg/kg) were seen to be high when compared with other PAHs. In apama and ramsi black cod, fluorine was BDL of 0.001mg/kg and fluoranthene concentration was found to be high with values of 0.375mg/kg and 0.554mg/kg respectively when compared with other PAHs.

Polycyclic aromatic hydrocarbons are ubiquitous anthropogenic pollutants that can be biologically amplified to high concentrations in food webs. Due to their lipophilicity, persistence and high toxicity, these residues are readily accumulated in tissues on non-target living organisms where they may cause detrimental effects. PAHs are toxic, carcinogenic and mutagenic to all organisms including humans (9). The metabolites of PAHs may bind to proteins and DNA which causes biochemical disruption and cell damage in animals and cancer in humans.

Out of the twelve PAHs identified in the head of the three stock fishes studied, Fluorene, anthracene, acenapthene and pyrene are less carcinogenic while Dibenzyl(a,h) anthracene, Benzo (k) fluoranthene, Benzo (a) pyrene, Benzo (g,h,i) perylene and Benzo (b) fluoranthene are highly carcinogenic.

Bioaccumulation of these carcinogenic PAHs were seen in the head of the three stock fish species studied but in minute quantities with cod having the highest bioaccumulation of Benzo (g,h,i) perylene and Benzo (b) fluoranthene.

The PAHs stated here are lower than the concentrations reported by some researchers in their investigation from 4 species of fish at Degele community, Nigeria (Nworu *et al.,* 2021).

According to Harvey (1997), PAHs are influenced by various sources in different types of environments, including industrial and domestic effluents, atmospheric deposition, surface and groundwater runoff. These specific pollution factors are found in each locality and can potentially increase the concentration of PAHs, especially in areas close to urban or industrial sites with higher contamination. Due to their specific molecular structure, PAHs can exhibit high volatility, allowing them to reach distant locations and consequently be ingested by humans. (Food and Agriculture Organization, 2020). The fact that fishing has been the primary source of food available for human consumption at the global level, providing nutrition and food input for various families benefiting from fishing as a source of income and fish as the main source of food, demonstrates the significant and growing role of fishing in providing food, nutrition, and employment.

The FAO report also highlights the importance of considering the quality of the input to be consumed to ensure improved food and nutritional security, while impacts on supporting ecosystems occur. Fish and fishery products are recognized as some of the healthiest and least impactful foods on the planet. For these reasons, it is important to develop national, regional, and global strategies for food and nutrition security to ensure the elimination of hunger and malnutrition.

In a systematic review by Monteiro *et al.,* (2023), the study focuses on PAHs contamination in elasmobranchs, along with associated risks to human health, highlighting the importance of PAHs for both aquatic life and human health.

From a public health perspective, a systematic study on PAHs in fish (both fresh and dried) in Nigeria was conducted, expanding the scope to include food preparation techniques. It was identified that PAHs are emerging as significant contaminants in smoked and dried fish, with smoking techniques contributing to the PAHs load in fish (Emoyoma *et al.,* 2023).

Additionally, author Diop *et al.,* (2023), in their research, examined the PAHs content in four species of smoked fish from different regions of Senegal, once again reinforcing the global concern about PAH contamination in fish and fishery products.

With the increasing human exposure to PAHs, there is a need for further studies to delineate the extent of human exposure in relation to fish consumption. Continuous monitoring of the presence and concentrations of PAHs worldwide is essential to determine changes and variations in environmental health, as this is a high-impact issue that threatens entire ecosystems.

Summary of Findings

The following are the summary of the findings:

The three stock fish samples analyzed showed that the fish species had high quality protein, essential and non-essential amino acids and fatty acids.

There was heavy growth and occurrence of fungi/bacteria on the inoculated samples of the three stock fish species.

Out of all the heavy metals analyzed, mercury was observed to the highly bio-accumulated by the three stock fish species especially ramsi black cod.

Bioaccumulation of these carcinogenic PAHs were seen in the head of the three stock fish species studied but in minute quantities with cod having the highest bioaccumulation of Benzo (g,h,i) perylene and Benzo(b) fluoranthene.

CONCLUSION

Conclusively, the result obtained in this study has provided scientific information and detailed knowledge of the proximate, amino acid and fatty acid composition, microbial load, heavy metals and PAHs concentration of these three important stock fish species. The results showed that the fish species had high quality protein, essential and non-essential amino acids, saturated, monounsaturated and polyunsaturated fatty acids.

The three stock fishes are excellent sources of fatty acids and amino acids and are good supplement for polyunsaturated omega-3 in diet. The fishes contain essential fatty acids particularly docosahexaenoic acids and eicosapentaenoic acids and essential amino acids for promoting improved health, prevention and healing of wounds and diseases in humans.

Overall, cod appears to be best as diet for humans due to its relatively high nutrient components and the ratio of polyunsaturated: saturated fatty acid followed by Apama and ramsi black cod.

Sea food such as stock fish and crayfish were found to be potential vectors in the transmission of opportunistic pathogenic microorganisms. This study confirms the occurrence of different pathogens in the samples of stock fish and this could be due to improper handling, improper storage and dirty environment in which they are displayed These could pose potential public health risk if not adequately processed hygienically before consumption.

RECOMMENDATIONS

The following are the recommendations of the findings:

1. Proper and hygienic storage of stock fish in market places
2. Buyers should not be allowed to touch food stuffs before buying them
3. Traders should buy quantity of product they can sell off within the shortest period to avoid over storage and spoilage.

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